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(Distribution of Phosphates and Silicic Acid in the Water of the Northern Part of the Indian Ocean)

by

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TRUDY INSTITUTA OKEANOLOGII
VOL. LXIV
Pp. 102-114

MOSCOW 1964

Translator: M. Slessers
Editor : R. A. Hough
Typed by : C. Sims

U. S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C.
1967

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ABSTRACT

The distribution of the dissolved mineral phosphates and silicates in water of the northern part of the Indian Ocean is discussed. The content of phosphates in surface water oscillates from 0.1 µg-at P/l (Bay of Bengal and Andaman Sea) to 0.4 µg-at P/l (Arabian Sea and to southeast of Ceylon) and depends on seasons.

The maximum content of phosphates in the Arabian Sea and the Bay **of Bengal is** 2.9 µg-at P/l **and to the south of 10°S in the open** part of the Indian Ocean the **maximum** content of phosphates is 2.4 µg-at P/l.

The content of total organic phosphorus is not more than 0.5 µg-at P/l.

The distribution of dissolved silicates is characterized by constant increase from the thermocline layer to the bottom. The maximum content of silicates is 150-160 µg-at Si/l in the Arabian Sea, 140 µg-at Si/l in the Bay of Bengal and 130-140 µg-at Si/l in the open northern part of the Indian Ocean.

The content of dissolved mineral phosphates and silicates is compared with water circulation, plankton and seasons.

The author

DISTRIBUTION OF PHOSPHATES AND SILICIC ACID IN THE WATER OF THE NORTHERN PART OF THE INDIAN OCEAN

During the 33rd cruise of the Vityaz', we determined the dissolved mineral phosphorus and silicic acid concentration at each station, but at some stations we determined the gross amount of phosphorus. Samples were obtained from all standard depths.

Dissolved phosphorus (phosphates) was determined by the Denije-Atkins method modified by Bruyevich; the gross quantity of phosphorus was determined by the Harvey method (1948) with the application of an autoclave. Standard solutions were prepared in sea water with low phosphate content by introducing corrections for the quantity of phosphates in it. Silicic acid was determined by the Diener-Vandenbulk method modified by Isayeva (1958). Standard solutions were prepared in sea water containing a known quantity of silicon.

The quantity of mineral phosphorus and silicon dissolved in sea water depends on their use by phytoplankton in the photosynthetic layer, the rate of mineralization of organic matter, and intermixing of water with various quantities of phosphates and silicic acid.

§1. Dissolved Mineral Phosphorus (Phosphates)

Arabian Sea (October-November). Intense biological activity in the water of this sea leads to considerable quantitative variation of biogenic elements, including phosphates. The surface water is characterized by a small quantity of phosphates not exceeding 0.4mcg-at/l (mg-at/l). In the first density discontinuity layer and under it (at the depth of 50-75m in the open part of the Arabian Sea and 20-50m off the coast) the quantity of phosphates sharply increases (Fig. 1. St. 4852). The concentration of phosphate phosphorus reaches 2.0 mcg-at/l at the depth of 100-150m. With a further increase in depth, the concentration of phosphates increases rather uniformly, reaching 2.80-2.90mcg-at/l. This maximum concentration is preserved to the depth of 1700-1800m, after which the content of phosphates decreases, reaching 2.30-2.40 mcg-at/l in bottom layers. Inverse regularity is observed in the quantity of oxygen and pH*: both of them decrease in intermediate depths below the density discontinuity layer (zone with minimum values lies in layer 150-1500m) and increase toward the bottom. The boundaries of typical

*See paper by Ivanenkov, Vintovkin and Shatskov in this issue, p. 115.

quantitative variations of these elements basically coincide with the boundaries of phosphate variations. This type of distribution is obviously explained by the fact that at depths with maximum values of phosphates the mineralization of organic matter and the utilization of oxygen associated with it ceases. As a result, /103 the concentration of phosphates either remains unchanged-- provided no intermixing with waters having less phosphates occurs at these depths--or decreases, if such an intermixing occurs. In the Arabian Sea one can observe such intermixing with the bottom water of Antarctic origin, which contains less phosphate. In the Andaman Sea, the deep part of which is separated from the Bay of Bengal by sills 1400-1600m deep, and the exchange of bottom water is impeded, only an insignificant (0.1mcg-at/l) decrease of phosphates is noted after the maximum concentration has been reached.

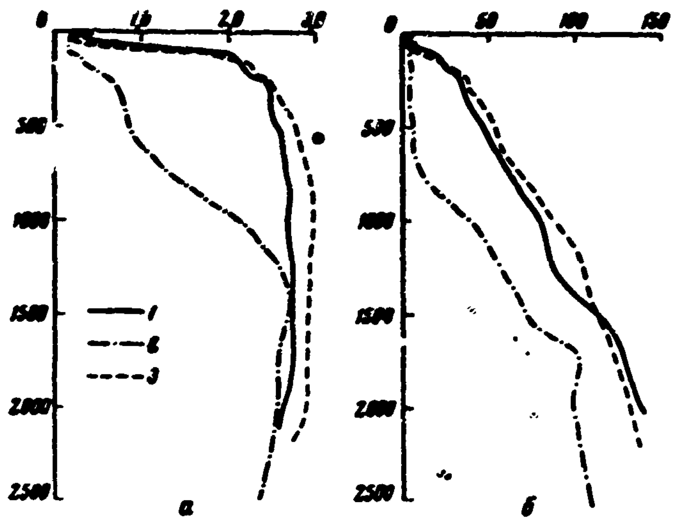

FIG. 1. Vertical Distribution of Phosphates (a) and Silicic Acid (b) (mcg-at/l)

1--St. 4852, λ--lat. 15°07'N, --long. 66°01'E;
2--St. 4888, λ--lat. 24°04'S, --long. 71°17'E;
3--St. 4935, λ--lat. 15°20'N, --long. 87°00'E.

In cross sections along long. 66°E and 71°E (Fig. 2, 3) one can see the typical features of the vertical distribution of phosphates. In cross section along long. 66°E one can notice a certain decrease in the content of phosphates at intermediate depths south of lat. 5°N, which is associated with the influence of the open part of the Indian Ocean, where the zone of maximum concentration lies considerably deeper than in the Arabian Sea.

In the cross section extending along long. 71°E this phenomenon is less pronounced within the boundaries of the sea; this is possibly associated with the effect of the Maldive Islands, which impedes the penetration of southern water into the Arabian Sea. A similar decrease of phosphates is observed in the equatorial zone.

When examining the horizontal distribution of phosphates, one can notice some typical features in the individual portions of the Arabian Sea. The quantity of phosphates in surface water (see Fig. 4 in paper by Kabanova on p. 91 in this issue) fluctuates from 0.2mcg-at/l in southwestern part to 0.4mcg-at/l in the central and northern parts. A tendency toward a decrease of phosphates in the surface layer in the east-west direction is coordinated with the variation of plankton biomass in layer 0-100m. According to data by Ponomareva and Naumova (1961), the plankton biomass in the western part of the Arabian Sea is somewhat greater than in the eastern part, i.e. in all probability, a somewhat decreased quantity of phosphates in the western part of the Arabian Sea is caused by a more intense consumption of the matter by plankton.

At the depth of 100m (Fig. 4) the distribution of phosphates in /105 the water of the Arabian Sea changes its pattern in comparison to their distribution at the surface. The maximum values of phosphates (2.2mcg-at/l) were observed in the western part of the sea. Somewhat smaller values (1.5-1.8mcg-at/l) were observed in the eastern part. Such a pattern of distribution is caused by a greater quantity of plankton in the western part of the sea, which induces a more intense production of organic matter: its decomposition creates a greater quantity of biogenic mineral forms, including phosphates.

At the depth of 600m (Fig. 5) the distribution of phosphates is rather uniform allover the Arabian Sea. Nevertheless, a certain increase in the quantity of phosphates in the southwest-northeast direction is noted (from 2.5 to 2.7mcg-at/l). It is possible that the higher quantity of phosphates in the eastern part of the sea at the depth of 600m, reflects a higher plankton development in that part of the Arabian Sea in the preceding (winter) season (Bogorov, Vinogradov, 1961).

In the Gulf of Aden (due to its position) the distribution of phosphates shows the regularities that are typical not only of the gulf itself but also of the Red Sea: the minimum value of phosphates is in the surface layer (see Fig. 4 in the paper by Yu. G. Kabanova in this issue, page 91); this is evidently the result of their more intense consumption by plankton; relatively

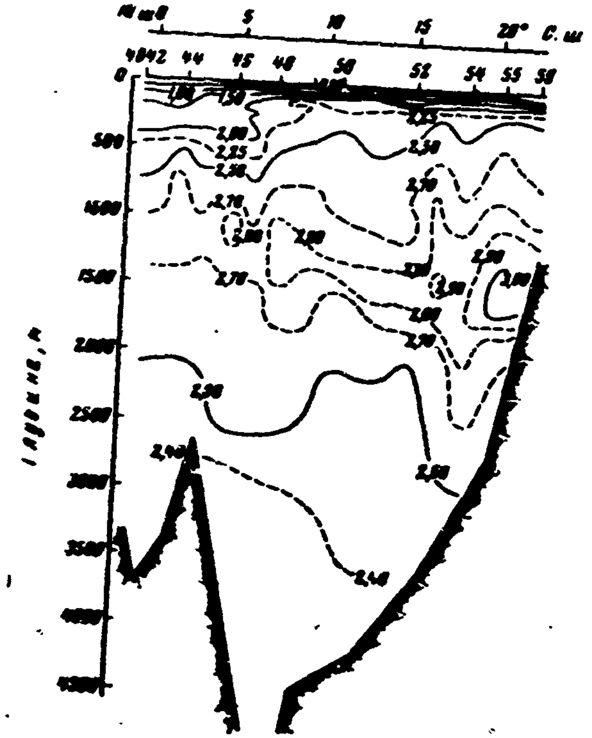

FIG. 2. Distribution of Phosphates (mcg-at/1) in cross section across the Arabian Sea along long. 66°E (18-29 November 1960).

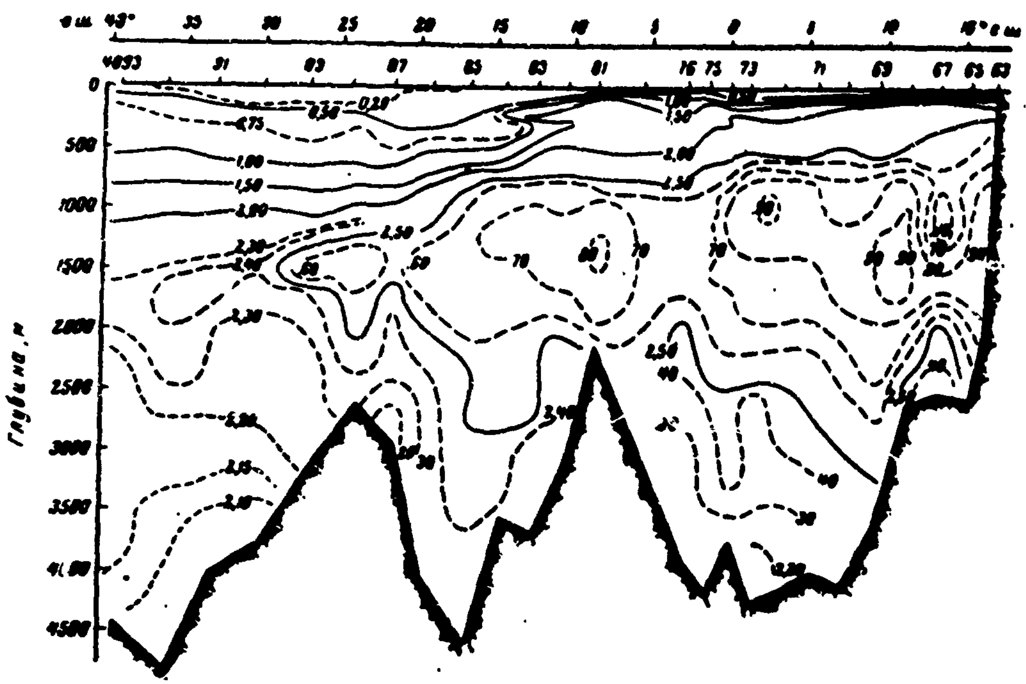

FIG. 3. Distribution of Phosphates (mcg-at/1) in cross section along long. 70°E (7-21 December 1960).

higher concentrations (1.9mcg-at/l) are observed at the depth of 100m (see Fig. 3), which results from the mineralization of organic matter of phytoplankton; sharply reduced concentrations (1.6-2.4mcg-at/l) are noted at the depth of 600m (see Fig. 5), which results from the influx of Red Sea water characterized by a paucity of phosphates.

The Somali Current area occupies a special position. Here the surface layer contains less phosphates; 0.3mcg-at/l at the surface and 0.8-1.0mcg-at/l at the depth of 100m. The decrease is caused not so much by phytoplankton but rather by a diminished influx of bottom water into the surface layer as the current weakens during the autumn season.

The open northern part of the Indian Ocean (December-January). In the open part of the Indian Ocean, the distribution of phosphates is affected by a deeper position of the denisty discontinuity layer, a decrease of vertical density gradients, a decrease of primary production as a result of insignificant development of phytoplankton; also, the deep Antarctic water with an insignificant quantity of phosphates affects the situation. The quantity of phosphates in the surface layers of the northern part of the Indian Ocean, which equals approximately 0.3mcg-at/l, decreases south of 20°S to 0.2mcg-at/l and more.

The cross section along 70°E (see Fig. 3) gives a conspicuous idea on the vertical distribution of phosphates. The general character of the distribution of phosphates in this cross section is similar to their distribution in other meridional cross sections in the Indian Ocean. North of the South Equatorial Divergence one can find increased concentrations of phosphates near the surface; but south of the divergence, at depths exceeding 1000m. In the northern part of the cross section, the phosphate maximum is 2.9-2.7mcg-at/l, and it is found in layer 700-2000m. In the southern part of the cross section, the quantity of phosphates equals only 2.4-2.3mcg-at/l, and it is found in layer 1500-2300m. The distribution of phosphates in cross section 71°E is characterized by isolated areas with great quantities of phosphates (see Fig. 3). A similar situation was observed by V. N. Invanenkov and F. A. Gubin (1960) who explained the phenomenon by the seasonal changes in the content of phosphates and other chemical elements in the water of the Arabian Sea.

When moving southward to the open part of the ocean, high and low concentrations of phosphates are observed in the water (centers lying at a depth of 1000-1500m). On the basis of distance between the centers of areas with high phosphate content and the change of seasons (once a year), V. N. Invanenkov and F. A. Gubin attempt to calculate the velocity of movement of north-Indian water. /107

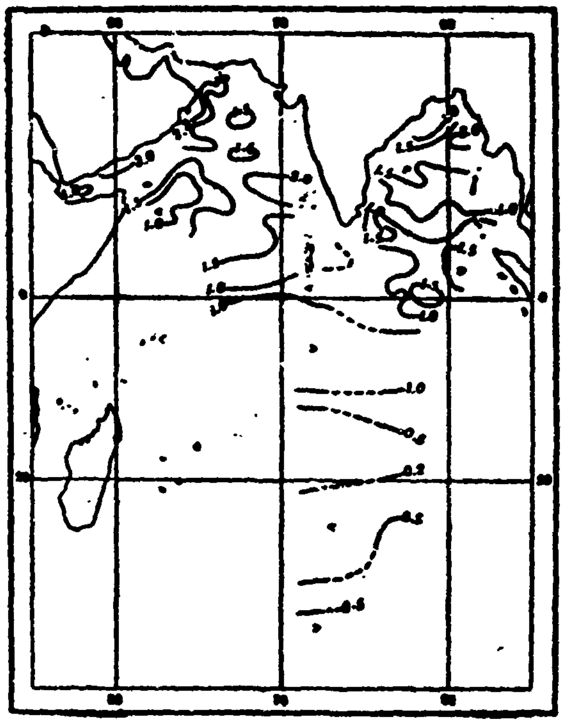

FIG. 4. Distribution of Phosphates (mcg-at/l) at the Depth of 100m (October-March 1961)

FIG. 5. Distribution of Phosphates (mcg-at/l) at the Depth of 600m (October-March 1961)

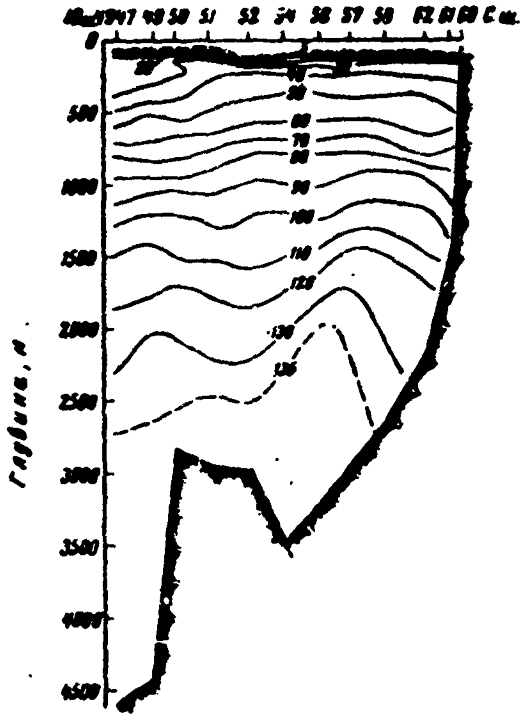

FIG. 6. Distribution of Phosphates (mcg-at/l) on Cross Section in the Bay of Bengal along 91°E (Dec.-Feb. 1961)

A tendency toward a decrease of phosphates in the north-south direction is also observed in the horizontal distribution of phosphates in the open part of the Indian Ocean.

The Bay of Bengal and the Andaman Sea (Feb.-March). The distribution of phosphates in the Bay of Bengal is very similar to that observed in the Arabian Sea. The quantity of phosphates in the surface layer is somewhat smaller than in the Arabian Sea (0.1-0.2mcg-at/l). The phosphate concentration increases rapidly below the density discontinuity layer, reaching 2.0mcg-at/l at the depth of 150m (see Fig. 1, St. 4935). The maximum concentration of phosphates (2.8-2.9mcg-at/l) is observed at depths of 800-2000m; toward the bottom, the value somewhat decreases (to 2.30mcg-at/l). In cross section at 91°E the pattern represents the entire gulf (Fig. 6).

In the Andaman Sea, which is characterized by a small quantity of phosphates (less than 0.10mcg-at/l) in the surface layer, one

can observe the greatest stability for layers with higher concentrations of phosphates (2.80-2.90mcg-at/l); as a rule, such concentrations do not decrease below 2.70mcg-at/l. The reason for this is that the exchange of waters with smaller concentrations of phosphates is impeded here because the Andaman Sea is separated from the Bay of Bengal by a submarine sill 1400-1500m deep.

§2. Organic Phosphorus

The quantity of organic phosphorus in a given area can be determined by the difference between the gross value and the dissolved mineral phosphorus. The difference shows the value of organic phosphorus in dissolved and suspended form (total organic phosphorus). Table 1 lists the values of gross, dissolved mineral and total organic phosphorus in the 0-200m layer for several stations in the northern part of the Indian Ocean.

The maximum values of total organic phosphorus, reaching 0.50mcg-at/l, are limited to the more productive areas (Arabian Sea, Table 1, St. 4795, 4854, 4568). /108

Such small values of organic phosphorus for such a rich plankton region, as is the Arabian Sea, can be explained by a high rate of mineralization of organic matter which eliminates the accumulation of phosphorus. The maximum values of organic phosphorus with depth are limited to the density discontinuity layer. The open part of the Indian Ocean is characterized by a small quantity of organic phosphorus in the surface layer; the quantity increases in the discontinuity layer to 0.3mcg-at/l (Table 1, St. 4890).

As to the content of organic phosphorus, the water of the Bay of Bengal occupies an intermediate position (Table 1, St. 4936). The Andaman Sea has low values (Table 1, St. 4969).

The concentrations of organic phosphorus in the Indian Ocean are far below the concentrations observed in other areas of the World Ocean (the Arabian Sea approaches the Sea of Okhotsk with respect to productivity) where the level of productivity is about the same. /109

Table 2 lists some data which represent the mean concentrations of total organic phosphorus for some seas and parts of oceans.

§3. Dissolved Mineral Silicic Acid

The Arabian Sea. The variation of silicic acid with depth is similar to variations of other biogenic elements (phosphates,

Table 1

Quantity of Gross, Dissolved Mineral and Total Organic Phosphorus (According to Yu. G. Kabanova 1961)*

Station	[illegible]			[illegible]			[illegible]		
Coordinates and dates of sampling	φ [illegible] N λ [illegible] E 28.X—60			φ [illegible] N λ [illegible] E 23-XI—60			φ 11°16'9 N λ [illegible] E 8.XII—60		
Depth	Gross	Diss. Min.	Total	Gross	Diss. Min.	Total	Gross	Diss. Min.	Total
0	0,40	0,14	0,28	0,56	0,31	0,27	0,52	0,42	0,10
10	0,44	0,12	0,32	0,58	0,23	0,35	0,52	0,30	0,13
25	0,80	0,35	0,45	0,61	0,25	0,36	0,90	0,39	0,51
50	2,00	1,52	0,48	0,58	0,27	0,31	0,65	0,30	0,35
75	1,92	1,68	0,24	1,42	1,42	0,00	—	—	—
100	2,13	1,90	0,23	1,08	1,05	0,03	2,08	2,00	0,08
150	2,19	1,90	0,29	2,58	2,32	0,26	—	—	—
200	2,25	2,06	0,19	2,61	2,42	0,19	2,53	2,45	0,08

Table 1 (End)

Station	[illegible]			[illegible]			[illegible]		
Coordinates and dates of sampling	φ 30°01'8 S λ 71°12'8 E 24.XII — 60			φ 13°34'9 N λ 86°51'9 E 2.II — 61			φ 11°30'3 N λ 95°15'6 E 3.III — 61		
Depth	Gross	Diss. Min.	Total	Gross	Diss. Min.	Total	Gross	Diss. Min.	Total
0	0,16	0,16	0,00	0,25	0,13	0,12	0,20	0,06	0,14
10	—	—	—	0,31	0,13	0,18	0,20	0,06	0,14
25	0,16	0,16	0,00	0,48	0,14	0,34	0,20	0,06	0,14
50	0,19	0,16	0,03	0,48	0,14	0,34	0,24	0,06	0,18
75	0,48	0,16	0,32	—	—	—	0,97	0,84	0,13
100	0,45	0,16	0,29	—	—	—	—	—	—
150	0,48	0,42	0,06	2,26	2,16	0,10	2,00	1,93	0,07
200	—	—	—	2,74	2,61	0,13	2,19	2,13	0,06

*See page 85 of this issue.

Table 2

Content of Organic Phosphorus

Area Investigated	Quantity mcg-at/l	Note	Month	Literature
Sea of Okhotsk.	1.1	Deep areas average for 0-75m	June-Oct.	Mokiyevskaya (1958)
Bering Sea.	1.5	same	Sept.-Oct.	same
Sea of Japan.	1.6	"	Jan.-Feb.	"
Kuroshio.	0-5 1-2 3	0m 100m 1000m		Takeda (1956)
Oyashio	2-8 2-4 3	0m 100m 1000m		same
Pacific Ocean (NW part) .	0.1-0.2 0.2-0.3	0m 100m	July-Aug.	Chinook (Exp. 1958)
Atlantic Ocean NW part.	0.9		Feb.-March	Mokiyevskaya (1958)
Sargasso Sea	0.3		Feb.-March	same
Indian Ocean (central part	0.1-0.2	Mean for 0-75m	Dec.	Kabanova (1961)
Arabian Sea	0.3-0.4	same	Oct.-Nov.	
Bay of Bengal	0.2-0.3	"	Feb.-March	
Andaman Sea	0.1-0.2	"	March	

nitrates)--namely, their quantities increase from surface to bottom. But the quantity of silicic acid increases more gradually with depth in comparison to phosphates or nitrates and continues to increase to the bottom. In the Arabian Sea the quantity of silicic acid in the surface layer does not exceed 3-4mcg-at/l. In the density discontinuity layer the quantity of silic acid increases erratically and at the depth of 100m reaches 15-20mcg-at/l. Further variation with depth is rather uniform to the bottom. At the depth of 3000-4000m the maximum value is reached--namely: 150-160mcg-at/l (see Fig. 1, St. 4852). This is a typical pattern in the vertical distribution of silicic acid in the Arabian Sea.

When examining the horizontal distribution, one can single out /110
individual areas with specific characteristics. At the depth of 100m (Fig. 7), the central part of the Arabian Sea stands out: here the quantity of silicic acid is smaller (10-15mcg-at/l) than it is in coastal areas (20mcg-at/l). This difference can be explained by the use of silicic acid by diatoms which were observed in the entire central sector and especially in the northern part of the sea (100-1000 cells per $1m^3$ in the 0-100m layer).*

In the Persian Gulf in the northern part of the Arabian Sea we observed an area with large quantities of diatoms (1000-2000 cells per $1m^3$ in the 0-100m layer); also the quantity of silicic acid was high here (20mcg-at/l).

In the Gulf of Aden the quantity of silicic acid at the depth of 100m is about equal to the mean value for the Arabian Sea (15mcg-at/l), although development of diatoms is more intense in the Gulf of Aden than in the Arabian Sea (1000-2000 cells per $1m^3$ in the 0-100m layer).

At the depth of 600m (Fig. 8) the quantity of silicic acid in the water of the Arabian Sea exceeds somewhat 80mcg-at/l; this was observed throughout the investigated area. In the Gulf of Aden, at the depth of 600m, a relatively low quantity of silicic acid (50-60mcg-at/l) was observed, which is associated with the influx of Red Sea water. This pattern was also noted when examining the distribution of phosphates.

A rather profuse development of diatoms (1000-2000 per $1m^3$ in the 0-100m layer) was noted in the area of the Somali Current. The concentration of silicic acid in this area is far below that in

*See paper by Zernova and Ivanova in this issue, p. 255.

the Arabian Sea (5-10mcg-at/l at the depth of 100m and less than 70mcg-at/l at the depth of 600m). A lower quantity of silicic acid at the depth of 100m is caused by diatoms, but at the depth of 600m the effect of Red Sea water is evident.

The open northern part of the Indian Ocean. This part of the ocean is characterized by very small quantities of plankton and small vertical density gradients. The quantity of silicic acid in the surface water reaches 5mcg-at/l in the equatorial belt and decreases to 2 mcg-at/l south of the South-Equatorial Divergence. The quantity of silicic acid increases with depth, but at a considerably slower rate than in the Arabian Sea. At 20°S the concentration of 20mcg-at/l is reached only at the depth of 700-900m (in Arabian Sea at 150m). The maximum concentrations of silicic acid, which are observed in bottom layers, equalled 130-140mcg-at/l (see Fig. 1, St. 4888). In the cross section along 70°E (Fig. 9) the mentioned properties of vertical distribution can be readily traced. Here one can distinguish variations in the vertical distribution of silicic acid when transiting from the Arabian Sea to the open part of the Indian Ocean (increases in the depth of discontinuity for silicic acid, decrease in the vertical gradients of its quantity and decrease in maximum concentrations). At 12-18°S the zone of South-Equatorial Divergence is clearly pronounced.

Before describing the horizontal distribution of silicic acid in the northern part of the Indian Ocean, let us discuss briefly some of the characteristics of the development of diatoms whose quantity in this area is extremely small (0-100 per $1m^3$ in layer 0-100m). Several spots west of the Maldive Islands in the chagos Archipelago can be considered as exceptions; here the quantity of diatoms increases to 100-2000 per $1m^3$ in 0-100m layer. An extremely large quantity of diatoms was noted southeast of Ceylon (at places as many as 1000 per $1m^3$ in the 0-100m layer).

However, the increase of diatoms in these areas does not lead to /112
a decrease in the quantity of silicic acid which would be expected to occur as a results of its use by plankton. On the contrary, an increase in the quantity of silicic acid was observed in these areas (more than 20mcg-at/l per 100m; see Fig. 7). In this case, probably, the use of silicic acid is compensated by the influx of the compound as a result of upwelling.

At the depth of 100m one can clearly see a gradual decrease in the quantity of silicic acid in the north-south direction (from 20mcg-at/l at 10°S to 5mcg-at/l at 40°S).

FIG. 7. Distribution of Silicic Acid (mcg-at/l) at the Depth of 100m (Oct.-March 1961)

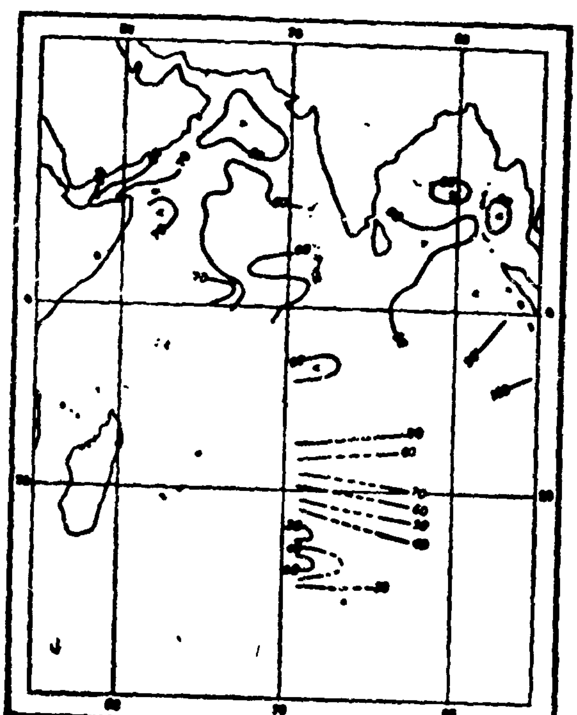

FIG. 8. Distribution of Silicic Acid (mcg-at/l) at the Depth of 600m (Oct.-March 1961)

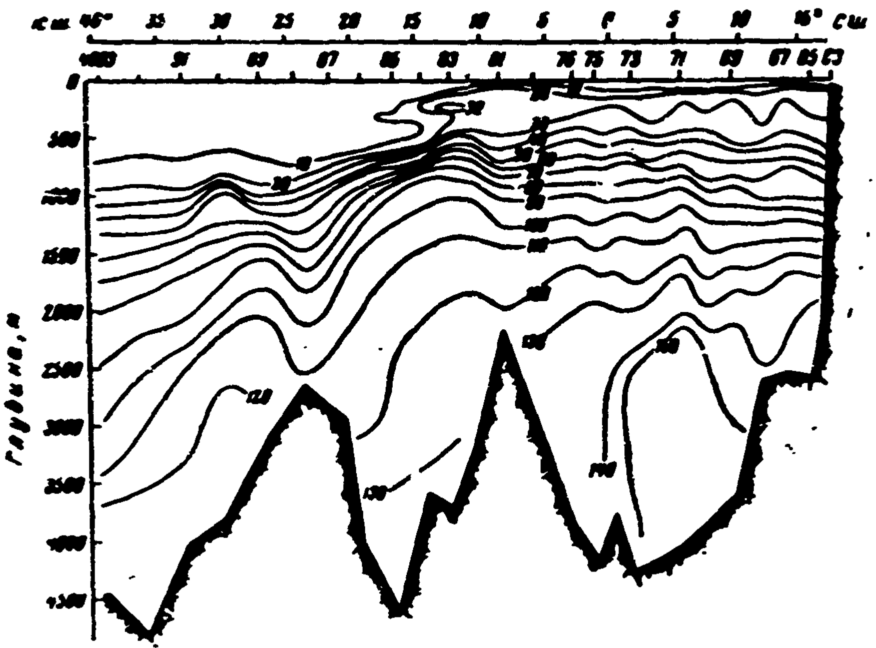

FIG. 9. Distribution of Silicic Acid (mcg-at/l) in Cross Section Along 71°E (7-26 Dec. 1960)

This phenomenon is also clearly evident at the depth of 600m (see Fig. 8); here the decrease in the quantity of silicic acid ranges from 90mcg-at/l at 10°S to 30mcg-at/l at 40°S. The South-Equatorial Divergence is clearly pronounced at this depth level (between 10-18°S). An increase in the quantity of silicic acid at the depth of 600m off the coasts of Sumatra and Java is associated with the upwelling of bottom water.

<u>The Bay of Bengal and Andaman Sea</u>. According to many physical and chemical properties, the Bay of Bengal has much in common with the Arabian Sea. From a biological point of view the Bay is sufficiently productive, though not quite as productive as is the Arabian Sea. Therefore, the vertical distribution of biogenic elements, including silicic acid, in the Bay of Bengal is about the same as in the Arabian Sea. The quantity of silicic acid in the surface layer is about 2-3mcg-at/l. A sharp increase in the concentration of the acid is observed in the density discontinuity layer, namely, to 10-15mcg-at/l, which continues to the bottom. The maximum is 140mcg-at/l. This pattern for the water of the Bay of Bengal is seen in the graph of vertical dis- /113
tribution (see Fig. 1, St. 4935) and in the cross section at 91°E (Fig. 10).

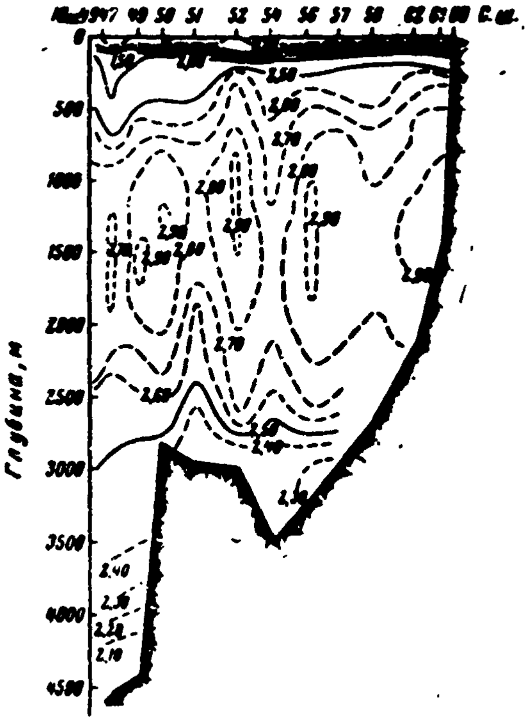

FIG. 10. Distribution of Silicic Acid (mcg-at/l) in a Cross Section Intersecting the Bay of Bengal Along 91°E (9-28 Feb. 1961)

The Andaman Sea is characterized by the same vertical distribution of silicic acid, but the maximum concentration does not exceed 90-100mcg-at/l. Such a low concentration of silicic acid can be explained by the fact that the exchange with the deep water of the Bay of Bengal, which contains large quantities of silicic acid, is impossible because of the submarine ridge.

The horizontal distribution of silicic acid in the Bay of Bengal is much more uniform than in the Arabian Sea. A quantity of 20mcg-at/l at 100m (see Fig. 7) was observed here only in restricted areas in the northern and southeastern parts of the Bay of Bengal and in the Andaman Sea. In other parts of the Bay of Bengal the quantity of silicic acid at the depth of 100m equals 10-15mcg-at/l, i.e. somewhat smaller than at the same depth in the Arabian Sea. At the depth of 600m the quantity of silicic acid in the Bay of Bengal and Andaman Sea varies very little (80-90mcg-at/l) (see Fig. 8).

CONCLUSIONS

1. The quantity of dissolved phosphate phosphorus in the surface water of the North Indian Ocean is determined by the quantity of phytoplankton and the intensity of primary production. The smallest amount of phosphates was observed in the surface water of the Bay of Bengal and the Andaman Sea (less than 0.1mcg-at/l), the largest in the Arabian Sea and SE of Ceylon (0.40mcg-at/l).

The distribution of phosphates in the Arabian Sea and the Gulf of Aden is subject to seasonal fluctuations.

2. The vertical distribution of phosphates depends on the depth of the density discontinuity layer and the vertical density gradients in it. In areas with high vertical density gradients (Arabian Sea, Bay of Bengal) one can observe a rapid increase in the concentration of phosphates below the discontinuity layer. In the central part of the ocean the increase occurs at a slower rate, which corresponds to a deeper position of the density discontinuity layer and smaller values of vertical density gradients. The maxi- /114
mum values (to 2.9mcg-at/l) and the thickest layer with maximum concentration are observed in the Arabian Sea, the Bay of Bengal and in the open northern part of the ocean. In the central part of the Indian Ocean, south of 10°S, the maximum values of phosphates decrease to 2.40mcg-at/l.

3. The quantity of total organic phosphorus in the water of the Indian Ocean is characterized by low values (maximum values to 0.5mcg-at/l are observed in Arabian Sea). A high rate of recovery of phosphorus can be assured.

4. The distribution of dissolved silicic acid is characterized by a uniform increase from the density discontinuity layer to the bottom.

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